ECOSYSTEMS

SPECIES DIVERSITY IN PLANTED PINE AND NATURAL HARDWOODS 24 YEARS AFTER SHEARING AND CHIPPING ON THE CUMBERLAND PLATEAU, TN

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Abstract--Plant species richness in 24 year-old planted loblolly pine (*Pinus taeda L.),* eastern white pine (*Pinus strobus* L.), yellow-poplar (*Liriodendron tulipifera* L.), naturally regenerated hardwoods, and mature hardwoods was compared using the North Carolina Vegetation Survey protocol. Comparisons were made in plots established after shearing and on-site chipping of a low quality hardwood stand on the Cumberland Plateau near Sewanee, TN in 1976. In 3 of the 6 plots representing each species, stems over 1.3 meters tall were injected with herbicide during the winter after harvest. Six years after planting, half of each eastern white pine plot was cleaned by manually or chemically removing only those trees essential to release the overtopped white pines. Three additional plots were installed in 2000 in the surrounding mature forest. Data collected in 2000 included species presence and cover class for a log10 series of nested square subquadrats (0.01, 0.1, 1 .0, 10, and 100 square meters) within a 900 square meter quadrat for each of the 0.4 hectare plots. A total of 159 plant species (excluding grasses) were encountered within the twenty-seven 900 square meter plots. Sixty-three were found in all 5 stand types. Thirty-nine were found in only one stand type, with the largest number (10) found in loblolly pine and yellow-poplar. Plant species richness beneath the loblolly pine was not significantly different from planted yellow-poplar, natural regeneration, or the surrounding older hardwood forest. Eastern white pine, however, exhibited reduced plant richness relative to the other stand types. The effects of tree injection on plant richness varied with stand type and plant form. While woody plant species declined slightly in all plot types, herbaceous species tended to decline in pine plots and increase in the hardwood plots. The effects of successive competition treatments on plant species richness in eastern white pine were cumulative (average 4.5 species per treatment).

INTRODUCTION

Many assumptions and beliefs exist regarding the effects of pine conversion on the biodiversity of our native hardwood forests. The public is concerned that replacing hardwoods with planted pine or using silvicultural practices such as competition control will reduce plant species diversity. While various studies have been initiated to address the effects of silvicultural practices on the floral diversity of harvested hardwood stands (Baker and Hodges 1998, Hammond and others 1998, McMinn 1998, Wender and others 1999) fewer studies have addressed understory composition of planted pine (e.g., Krochmal and Kologiski 1974), and none are available that compare the understory of planted pine to that of similar age hardwood stands on the Cumberland Plateau in Tennessee.

In the 1970's the Sewanee Silviculture Lab of the USDA Forest Service Southern Research Station initiated a series of studies to address land management opportunities for private landowners with cut-over, degraded hardwood stands. One such study (McGee 1980), investigated the potential of clear-felling by in-woods chipping, followed by planting one of two species of pine (loblolly and eastern white), yellow-poplar, or allowing natural regeneration. In addition to providing valuable tree growth information, this study (now 24 years-old), provided an excellent opportunity to compare the floral diversity under different planted species to that of natural hardwood regeneration. Since two different levels of tree removal were used, harvest to a 10 centimeter dbh and harvest to 10 centimeters with the injection of the smaller residual stems, it was also possible to test the effect of woody competition control on plant species richness.

The objectives of the research reported here were to determine the effects of 1) planting pine, planting yellow-poplar or natural hardwood regeneration and 2) control of woody competition at harvest on the plant richness (non-woody and woody vascular plants) of a low-quality hardwood stand on the Cumberland Plateau near Sewanee, TN.

STUDY AREA

The 15 hectare (37-acre) study area, is located on the Cumberland Plateau near Sewanee, TN (35°12'30"N and 85°55'W). It is typical of Landtype 1 (Undulating Sandstone Uplands) (Smalley 1982). The moderately deep to deep soils developed in loamy residuum from sandstone and some shale. Sandstone outcrops in places. The soils are classified as fine-loamy, siliceous, mesic Typic Hapludults. Elevation ranges from 579 to 594 meters. Annual precipitation, averaging 140 centimeters, is well distributed; September and October are the driest months.

The area was harvested in 1976 by shearing and chipping (McGee 1980). Prior to harvest, the stand consisted primarily of culls and low quality hardwood stems. The dominant

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overstory species were white oak (*Quercus alba* L.) and scarlet oak (*Quercus coccinea* Muenchh.). Site index estimates ranged from 17 to 23 meters for oak, but accurate estimates were difficult to obtain because there were few suitable overstory trees (McGee 1980). The harvest removed 1200 tons of green chips and a total of 30 tie logs or sawlogs from the entire 15 hectare area. All stems = 10 centimeters dbh were removed from the site during the shearing, leaving 125 to 1480 stems per hectare (mostly 5 - 8 centimeters dbh).

After harvest, twenty-four 0.4 hectare (1 -acre) plots were established and six plots were randomly selected for each of the following treatments: planting 1 .0 loblolly pine (LP), planting 2.0 eastern white pine (EWP), planting 1 .0 yellow-poplar (YP), and natural regeneration (NAT). Trees were planted at a 2.4 x 3 meter spacing. In three plots of each treatment, stems over 1.37 meters tall were injected (INJ) with herbicide during the winter after harvest. A square 0.1 hectare measurement subplot was established in the center of each plot. Six years after planting, half of each EWP plot was cleaned by manually or chemically removing only those trees necessary to release the overtopped white pines. The early growth and development of the trees have been reported in a series of publications (Hepp 1989, McGee 1980, McGee 1982, McGee 1986), the most recent of which was a report on a subset of the treatments after the fifteenth growing season (Dethero 1992).

METHODS

In the summer of 2000, a 900 square meter plot (30 meters x 30 meters) was established within the central measurement plot in each of the original 24 experimental plots. Three additional 0.4 hectare plots were established in regions of the adjacent forest that were not harvested in 1976 (UNCUT) to allow comparison of the diversity in the clear-cut plots to that of mature forest. A 900 square meter measurement plot was established in each.

A modification of the North Carolina Vegetation Survey protocol (Peet and others 1998) was used to compare the total plant diversity of the treatments. Each 900 square meter quadrat was subdivided into nine 10 x IO square meter modules. Two series of smaller subplots (0.01 , 0.1, 1 .0, and IO square meters) were nested within opposite corners of four of the nine 100 square meter modules.

The presence and cover class of each plant species were recorded for all nine 100 square meter modules within each treatment plot. In four of the modules, species presence was recorded within the two nested series of subplots. Thus for each species/treatment combination there were 3 replications of the 900 square meter plots, 27 of the 100 square meter subsamples (9 per plot) and 24 subsamples (8 per plot) for each of the smaller areas sampled (10, 1, 0.1, and 0.01 square meters).

In the fall of 2000, dbh, height class, and crown class for all stems = 1.3 meters tall (living and dead) were recorded by 100 square meter module for each of the twenty-seven 900 square meter measurement plots (only the basal area information will be included in this report).

Similarity of plant communities was investigated using the Czekanowsky Coefficient of Similarity (Czekanowski 1913). The Czekanowsky Coefficient includes both qualitative (presence/absence) and quantitative (abundance) data. The value used for species abundance was the number of 100 square meter plots in which a species was found rather than the actual number of stems. Coefficients range from 0 to 1, with 0 indicating no species in common, and 1 indicating the same number and same abundance present for each of the species.

Main effects (species; injection) and the interaction were tested at the a = 0.05 level using General Linear ANOVA models (SPSS). Duncan's Multiple Range Test was used to compare means when significant differences were detected.

RESULTS

A total of 159 plant species (excluding grasses) representing 119 genera and 24 families were encountered within the 27 900 square meter plots (table 1). These included 34 trees, 19 shrubs, 91 herbs, 9 vines, and 6 ferns. Sixty-three (40 percent) were found in all 5 plot types and 18 (11 percent) were found in all 27 of the measurement plots.

Thirty-nine (25 percent) of the identified species were found in only one plot type, the majority of which were herbs (25 species; table 2). The largest numbers of unique species (10) were found in LP and YP sites. The lowest numbers (6) were found in both UNCUT and NAT sites. Differences in numbers of unique species were due primarily to differences in numbers of herbs.

The Similarity Coefficient (Czenakowski 1913) based upon all plants in all 6 plots for each plot type indicated that the LP, YP, and NAT plots were more similar to each other than they were to the EWP plots (table 3). While coefficients averaged 0.84 among the non-EWP plots, the average similarity of EWP to the non-EWP plots was only 0.71. The coefficients for herbaceous species (0.66 average) were significantly lower than those for woody plants (0.84 average; $p < .0001$).

Table I-Comparison of species richness (number of species) by plant form across twenty-seven 900 square meter plots (3 mature mixed-oak forest, and 6 each of 24 year-old loblolly pine, eastern white pine, yellow-poplar and natural regeneration)

	All Forms	Trees	Shrubs	Herbs	Vines	Ferns
Totals[a]	159	34	19	91	9	6
Common[b]	63	21	8	27	6	1
Ubiquitous[c]	18	8	4	4	2	0
Unique[d]	39	6	5	25	2	1

[a]Total number of species fouind in the 27 study plots
[b]Number of species that were fuound in all 5 plot types
[c]Number of species that were fuound in all 27 plots
[d]Number of species that were fuound in only one plot type

Table 2-Number of unique[a] species by plant form in mature mixed-oak forest (UNCUT), and 24-year-old loblolly pine (LP), eastern white pine (EWP), yellow-poplar (YP) and natural regeneration (NAT)

	Plant Form					
	All Forms	Trees	Shrubs	Herbs	Vines	Ferns
Uncut	6	1	1	4	0	0
EWP	7	3	0	2	2	0
LP	10	1	1	8	0	0
NAT	6	1	1	3	0	1
YP	10	0	2	8	0	0

[a] Species found in only one plot type

Coefficients comparing INJ to NON-INJ plots of the same species were 0.75 (YP), 0.80 (EWP), 0.83 (NAT), and 0.85 (LP).

Average plant richness per 900 square meters ranged from a low of 59 species in EWP to a high of 71.3 in LP (figure 1). Numbers in YP, UNCUT, and NAT were intermediate (61.7, 66.7, and 69.0 respectively).

The size of the area sampled had an impact on apparent effects of the treatments. For example, tree species richness averaged 20.2 per 900 square meters and was not affected by either species or injection. When based upon the smaller 100 square meter plots, however, tree species richness did differ among species, with richness in EWP lower than in the other species (11 .O versus 14.3 average).

Table 3-Comparison of plant community similarity between plots of 24 year-old lobololly pine (LP), eastern white pine (EWP), yellow-poplar (YP) and natural regeneration (NAT) using the Czekanowski Similarity Coefficient" (based upon six 900 square meter plots for each type)

	Czekanowski Coefficient			
Plot type	LP	EWP	YP	NAT
LP	-	.75	.82	.81
EWP	-	-	.70	.69
YP	-	-	-	.89
NAT	-	-	-	-

[a]The coefficient was calculated: $2 \sum \min(X_i, Y_i) / (\sum X_i + \sum Y_i)$ where X_i = # of 100 m² plots in which species i occurs in plot type X, Y_i = # of 100 m² plots in which species i occurs in plot type Y, and (min (X_i, Y_i)) = the lesser # of 100 m² plots (type X or Y) in which species i occurs.

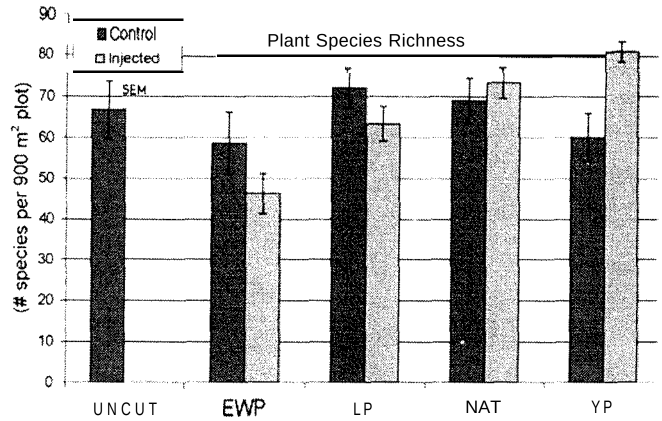

Figure 1 -Average total plant richness of injected and non-inject 900 square meter plots of mature mixed-oak forest (UNCUT), and 24 year-old loblolly pine (LP), easter white pine (EWP), yellow-poplar (YP) and natural regeneration (NAT).

The effects of tree injection on total plant richness varied with plot type (figure 1). While the within-species trend was for pine sites to exhibit decreased richness with INJ and hardwood sites increased richness, only in YP was the difference statistically significant. injection reduced the plant richness of the EWP(INJ) sites relative to all other treatments except EWP(NON-INJ) and YP(NON-INJ).

Woody species richness (shrubs + trees) was not significantly different in INJ and NON-INJ 900 square meter plots (figure 2), although there was a trend across all species for a reduction of approximately 3 species. While herbaceous species richness declined with INJ in pine plots by an average 8 species per 900 square meter plot, richness actually increased by an average of 8 species in the deciduous plots. (Only in YP was this difference significant at 0.05.)

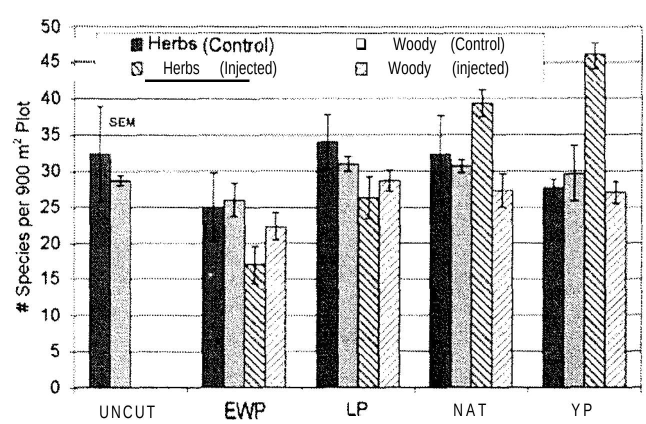

Figure 2-Average woody species richness (shrubs + trees) and herbaceous species richness (excluding grasses) of injected and non-injected 900 sq. meter plots of mature mixed-oak forest (UNCUT), and 24 year-old loblolly pine (LP), eastern white pine (EWP), yellow-poplar (YP) and natural regeneration (NAT).

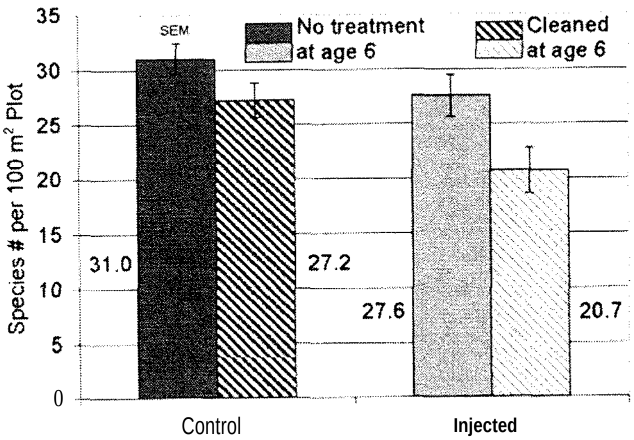

Figure 3-Effects of two successive competition treatments (immediately post harvest or at age 6) on the total plant species richness of 100 meter plots of eastern white pine (EWP).

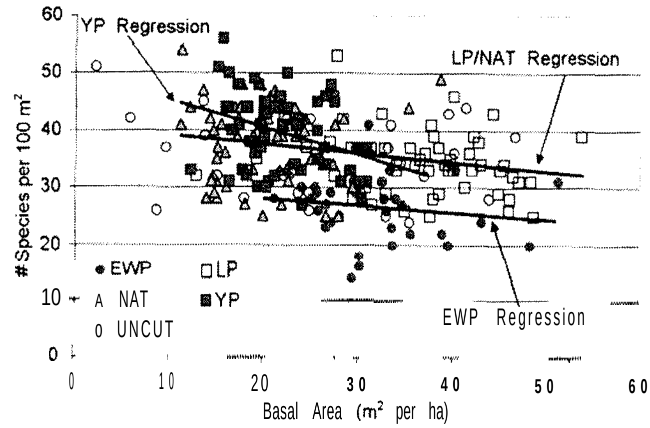

Figure 4—Relationship of plant species richness to the basal area of tall stems 1.3 meters tall within 100 square meter plots of mature mixed-oak forest (UNCUT), and 24 year-old loblolly pine (LP), eastern white pine (EWP), yellow-poplar (YP) and natural regeneration (NAT).

The effects of successive competition treatments on plant species richness in EWP were cumulative, with an average reduction of 4.5 species per treatment (figure 3). The timing of the treatment (immediately post harvest or at age 6) was not significant for the magnitude of the species change. However, the two treatments had different effects on the woody and herbaceous species. The species most impacted by the initial treatment were herbaceous (reduced by 3.8 species per 100 square meters versus 1 .l woody species). In contrast, the weeding at age 6 had little impact on the herbaceous species (0.8 species reduction), but did reduce the woody component by 3.6 species.

Current plot basal areas (all stems = 1.3 meters tall) were higher in the pine than in the hardwood plots. The NON-INJ plots averaged 30 square meters/hectare in the pines and 20 square meters/hectare in the hardwoods. INJ increased the overall basal area of the pines by 3 square meters/ hectare in EWP and 8 square meters/hectare in LP. INJ increased the average percentage of the total basal area that was pine from 58 to 69 percent in EWP and from 60 to 86 percent in LP. INJ decreased basal areas by an average of 1 square meter/hectare in both NAT and YP plots. Basal area in all of the hardwood plots was dominated by oaks (white, scarlet, and black (*Quercus velutina* Lam.)) except for some of the YP(INJ) plots which were dominated by YP.

Differences in plot BA (all stems = 1.3 meters tall) had little relationship with plant species richness in this study (figure 4). Only in YP was the slope of the regression significantly different from zero. However, there was a difference in the number of species per unit BA, as EWP stands exhibited a lower species number per given BA than all the other stand types, including LP. The relationship was similar if only pine basal area was considered in the analysis (data not shown).

DISCUSSION

Twenty-four year old clear-cut sites on the Cumberland Plateau planted to LP, YP, or allowed to regenerate naturally (NAT) to mixed hardwoods did not differ in plant species richness from the adjacent mature hardwood forests (UN-CUT). These results are not surprising to those who have planted LP on hardwood sites and had to control the hardwood and herbaceous competition that develops in the young stands. Richness has been shown to increase immediately after harvest and decline with time (Baker and Hodges 1998, Hammond and others 1998). Twenty-four years have likely been sufficient at this site to return the species numbers to the levels of the surrounding mature stand.

While there was not a significant difference in the woody plant richness of the non-EWP plots, there was likely a change in the relative abundance of different species, a pattern found after harvest in Southern Appalachian forests (Oliver 1980, Parker and Swank 1982). Numbers of unique species (those found only in one plot type) were actually higher in the planted sites and lowest in the uncut forest and naturally regenerated plots.

Areas planted to EWP did exhibit reduced plant richness. One possible explanation for the difference in EWP is the high leaf area it supports and the reduced light levels at the forest floor. However, even EWP plots with reduced basal area (pine or hardwood) and presumably more open canopies exhibited fewer species than LP, YP, or UNCUT plots with similar basal areas (figure 4). Because other coniferous species such as Eastern hemlock (*Tsuga canadensis* (L.) Carr.) have been shown to influence species distributions through effects on soil properties (Beatty 1984), one future area of investigation will be potential differences in soil properties beneath the EWP relative to the other plots.

Studies have shown variable effects of competition control on species richness in pine plantations. While woody competition control had no effect on understory species richness in 12-14 year old LP plantations in the Virginia Piedmont, canopy woody plant richness was reduced by either woody plant or herbaceous control (Shabenberger and Zedaker 1999). While there was no effect of broadcast herbicide treatments on the overstory or understory plant richness in planted LP on the Georgia Piedmont after seven years (Boyd and others 1995), non-pine woody competition control increased forb and grass cover in 8 to 11 year-old longleaf pine (*Pinus palustris* Mill.) plantations (Harrington and Edwards 1999).

The injection of residual stems at harvest had a negative impact on species richness in the planted pine sites in this study, but resulted in an increase in richness in the hardwood sites. While the only difference that was statistically significant (a = 0.05) was the increase with INJ in the YP plots, the downward trend within the pines was very consistent, and with a larger number of samples would likely have shown statistically significant differences as well.

The difference in the response of richness in the pine and deciduous hardwood plots is possibly due to differences in the rate of full site occupancy in the INJ pines and hardwoods. Injection in the pines likely allowed the fast growing pines to fully occupy the sites and prevented the successful establishment of other species. The overall slower growth of hardwoods, and the removal of some of the hardwood basal area through injection in the INJ hardwood plots would have provided additional resources (light, moisture, etc.) for other species to become established.

The increased richness in the injected hardwood sites was due to herbaceous, not woody, species. Woody plants declined slightly in INJ plots of all species (figure 2). While changes in woody plant species were generally small (losses of 1 to 4 per 100 square meters), changes in herbaceous species ranged from -8 in pines to +18 in YP. Hammond and others (1998) also found that changes in woody plant diversity were generally less than those of herbaceous species after harvest of southern Appalachian mixed oak sites.

The plots with the highest species richness and the greatest increase in richness with injection were the YP(INJ) plots. This is possibly due to the increased light that passes through YP crowns relative to oaks. While YP actually dominated some of the YP(INJ) plots, oaks (white, scarlet, and black) dominated all of the YP(NON-INJ) plots as well as all of the NAT plots.

While one possible explanation for differences in species richness beneath the pines could be the effects of high pine basal area, the explanation does not appear to apply to the results of this study. There was no apparent relationship between species richness and either total or pine basal area at either the 900 square meter or 100 square meter plot size except a slight decline in YP (figure 4).

CONCLUSIONS

The effect of planting pine on plant species richness will depend upon the species of pine planted. Species numbers in 24-year-old LP on the Cumberland Plateau were not significantly different from planted YP, NAT, or the surrounding older hardwood forest. Planting EWP, however, did reduce plant diversity, and competition control increased the overall effect.

The study area did not receive any intermediate stand treatments other than the release of EWP at age 6. Since injection of competing stems at harvest caused slight reductions in species richness, it is possible that more intensive management would have a greater impact on plant richness. It is interesting to note, however, that injection of residuals at harvest actually appeared to increase richness in the hardwood stands. Thus silvicultural harvest of mixed-oak stands may tend to foster greater plant richness than harvests which leave more residual stems on the site.

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INTEGRATION OF LANDSCAPE ECOSYSTEM CLASSIFICATION AND HISTORIC LAND RECORDS IN THE FRANCIS MARION NATIONAL FOREST

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Abstract-Geographic Information Systems (GIS) data and historical plats ranging from 1716 to 1894 in the Coastal Flatwoods Region of South Carolina were used to quantify changes on a temporal scale. Combining the historic plats and associated witness trees (trees marking the boundaries of historic plats) with an existing database of the soils and other attributes was the basis for exploring possible site types as defined by Landscape Ecosystem Classification (LEC) and historic vegetation.

Field plots were established using locations of the witness trees from the historic plats. The witness trees could then be used as a basis of comparison between past and present vegetation. From the field plots, four clusters of vegetation were delineated using Detrended Correspondence Analysis (DECORANA) and Two-way Indicator Species Analysis (TWINSPAN). Discriminant analysis revealed thickness of the A horizon, presence/absence of a B horizon, Landform Index (LI), and Terrain Shape Index (TSI) as discriminating variables in the model. These four site units revealed a soil moisture gradient ranging from very poorly drained soils to moderately well drained soils.

The historic witness tree data set was dominated by longleaf pine (70 percent). The comparison of historic witness trees to present vegetation showed a drastic decrease in longleaf across the landscape due to past management practices and the suppression of fire.

INTRODUCTION

The South Carolina Coastal Plain is home to some of the most biologically diverse ecosystems in the world. These ecosystems have been significantly altered by natural and anthropogenic activity over the past 10,000 years. Public pressures have prompted the United States Forest Service to manage National Forests as ecosystems (Brenner and Jordan 7991) having an array of uses and functions, rather than timber stands used only for the extraction of commodities.

An understanding of these ecosystems during presettlement times will prove to be invaluable for better management today. The objective of this study was to use Landscape Ecosystem Classification (LEC) and historical data to model presettlement (natural state) plant communities. This knowledge will assist in long-term studies of past ecological processes and provide a basis for the study of present modern day plant communities (Schafale and Harcombe 1982).

METHODS AND DATA ANALYSIS

Study Area

Field data were collected on 32 plots within Francis Marion National Forest (FMNF). These plots were located in areas of close proximity to locations of known witness trees from the historic plats. Witness tree data and the field plots encompassed some of the site units as defined by the Hilly Coastal Plain Province and Coastal Flatwoods Region LEC models for South Carolina Coastal Plain Province (Petitgout 1995).

Annual precipitation in the study area averages 47 inches and ranges from 39 to 55 inches. Summertime temperatures range from 65° to 90° F with temperatures in excess of 100° F occurring a few days most years. The average winter temperature is about 48° F with maximum and minimum temperatures of 60° and 35” F, respectively. The growing season is roughly 260 days (Long 1980).

Creating a Database

This project began with the creation of GIS (ARC/INFO) layers incorporating historic vegetation data and other cultural features from historic plats for areas in the FMNF. Fifty historic grant plats were initially acquired from the Charleston and Berkeley County records and digitized into the database, each as its own coverage (layer). These data were added to the already existing GIS database for FMNF. All of the vegetation, cultural features, and other relevant information were captured in the GIS. This information could then be used to perform spatial analyses and comparisons of the present vegetation and features in the FMNF versus the historic vegetation and features.

Sampling Procedures

In order to describe forest types in the areas defined by the witness trees, Landscape Ecosystem Classification (LEC) methodology was used to quantify vegetation and the underlying physical factors that help to discriminate among forest types. In preparation of going into the field, a map

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was created overlaying witness trees with the USFS forest type coverage using GIS. This map was used to identify mature stands (LEC calls for "steady-state") located in close proximity to the historic witness trees. Very few "steady-state" stands could be found throughout the FMNF, much less in the areas of witness trees where the study was restricted. This can be attributed to management practices and more so to the damage done to the forest by hurricane Hugo in 1989.

A circular 0.04 hectare plot was established in areas as delineated by witness tree data. Trees (no smaller than 4.5 inches diameter at breast height (dbh)), were measured for dbh and height for the entire 0.04 hectare plot. Seedlings, vines and herbaceous covers were sampled over the entire plot using a density class rating (Blanquet 1932/1951). Saplings (l-4 inches dbh) were tallied for a smaller subplot (0.01 hectare) in the center of the 0.04 hectare plot.

Soil samples were collected in three locations on each plot using a soil auger. Depth of the A and B horizons (C when there was no B) were determined in the field by averaging the three samples. Depth to maximum clay was also determined in the field. Maximum clay was a subjective measurement taken at the depth where the best ribbon could be made for the soil sample. No maximum clay was recorded for those soils determined in the field not to have B horizons. Soil samples from the A and B horizons (C horizon if no B existed) were composited for each plot. Texture analysis was performed in the lab, without the removal of organic matter, using the pipette method (Foth and others 1971).

Recent and ongoing studies in the southeastern Coastal Plain have shown that small differences in topography and landform can make a difference in the vegetative communities found and the site units derived (Stich 1994). For this reason, Terrain Shape Index (TSI) and Landform Index (LI) (McNab 1989, 1993) were recorded on each plot to determine the significance of these variables in distinguishing among site units.

Analytical Procedures

Vegetation data were summarized by species stratum for each plot. Relative density, relative basal area, and importance value 200 ((relative density + relative basal area / 2) x 100) were calculated by stratum for trees and saplings. Importance values were determined using relative frequency for seedlings, shrubs, and herbs. Where a single species occurred in more than one stratum, each instance was treated as a unique species or 'pseudospecies' (Carter 1994).

Detrended Correspondence Analysis (DECORANA) was the method of ordination used to analyze the vegetation data (Hill 1979a). TWINSPAN (Hill 1979b) was also used to analyze the vegetation data. DECORANA and TWINSPAN were used in the software package PCORDO. PCORD© is a windows based program used for multivariate analysis of ecological data (McCune and Mefford 1995).

Stepwise discriminant analysis and discriminant analysis (SAS 1990) were used to analyze the physical variables associated with the field plots. The soil variables used in the analysis were depth to maximum clay (inches), depth of soil horizon (inches), humus thickness (inches), and horizon texture. The landform variables used were Landform Index and Terrain Shape Index (McNab 1989, 1993). Stepwise discriminant analysis was used to determine the discriminating variables at the 0.20 significance level. The validity of the discriminant function was determined using resubstitution and cross-validation (SAS 1990).

Due to the small sample size of witness trees and dominance of longleaf pine in the sample, they were analyzed by looking at various relative frequency scenarios. The indicator or diagnostic species found in the ordination and classification were also compared to the witness trees and relative frequencies were observed. All of the basic statistics involving numbers of trees and area involved were conducting using GIS.

RESULTS AND DISCUSSION

Ordination and Cluster Analysis

The primary data matrix consisted of 32 plots and 307 species. A number of ordinations were performed to determine possible relationships between vegetation and the corresponding axes that represented a discernible environmental gradient. The first ordination was run using the exact groups delineated by TWINSPAN and then subsequent trials were performed in an attempt to achieve better classification and agreement between the ordination/ cluster analysis and the discriminant analysis. Personal judgement was used during group assignment based on knowledge of plot composition and characteristics.

Presence/absence data were analyzed for 32 plots and 307 species. DECORANA and TWINSPAN identified 4 groups. Axis 1 had a beta diversity of 3.8 standard deviations while axis 2 had a beta diversity of 4.3 standard deviations. A complete turnover in species should occur after 4 standard deviations along any of the axes (Hill and Gauch 1980). Numerous plots demonstrated disagreement in clustering by DECORANA and TWINSPAN. After studying the data closer, the clusters were modified. This was done systematically on a plot by plot basis and then rerunning the ordination as each cluster was altered by a single plot. Figure 1 represents the clusters that were the basis for the most accurate model using discriminant analysis.

Discriminant Analysis

Stepwise discriminant analyses were utilized to determine the significant physical variables that could be used to discriminate among the groups found using ordination and classification. Discriminating variables were identified and a linear model was created. Sixteen variables were entered during the stepwise discriminant analysis procedure. They were Landform Index (LI), Terrain Shape Index (TSI), root mat thickness (inches), depth to maximum clay (inches), A horizon thickness (inches), B horizon thickness (inches), presence/absence of a B horizon and relative proportions of sand, silt and clay in the A, B and C horizons. Five variables proved to be significant at the 0.20 level. These variables were (1) Landform Index (2) Terrain Shape Index

Table 1-Discriminant function equations of four ecological site units produced by discriminant analysis

	Ecoloaical Site Unit			
	Hydric	Mesic	Submesic	intermediate
Multiplier	Coefficient			
Constant	-17.48	-16.13	-5.64	-10.58
Landform Index	-77.05	143.33	53.42	-7.86
TSI	562.64	-2.23	298.33	530.98
B Horizon				
(Pres l/Absence 0)	1.08	-0.30	0.41	1.37
A Horizon				
Thickness (inches)	1.19	0.27	0.55	0.61
Percent Sand (C)	-0.58	0.05	-0.22	-0.51

Table 2-Field model discriminant function equations of 4 ecological site units produced by discriminant analysis

	Ecoloaical Site Unit			
	Hydric	Mesic	Submesic	Intermediate
Multiplier	Coefficient			
Constant	-12.17	-16.09	-4.9	-6.52
Landform Index	99.95	141.52	61.87	11.89
TSI	223.77	24.9	171.62	234.86
B Horizon				
(Pres l/Absence O)	-0.16	-0.20	-0.05	0.28
A Horizon				
(inches)	0.53	0.32	0.31	0.03

(3) thickness of the A horizon (4) presence/absence of B horizon and (5) percent sand in the C horizon.

Discriminant analysis was then used to determine how accurately these five significant physical variables could be used to classify the data into the four clusters delineated in figure 1. The discriminant function had a resubstitution classification rate of 88 percent and misclassified three plots. The cross-validation classification rate was 77 percent with seven plots misclassified. This represents the best model that could be created using all available data. The discriminant functions (model) for the initial run are in table 1. The correct site classification is the site unit with the highest sum of all the products of each site unit equation. In the discriminant model, a 1 represented the presence of a B horizon and a 0 represented the absence of a B horizon.

A second discriminant analysis procedure was performed to generate a model that could be used in the field. This field model was created using only those variables that were conducive to field measurement (table 2). Four of the five variables found to be significant (0.20) in the original stepwise discriminant analysis procedure were adequate for field sampling. These variables were (1) Landform Index (2) Terrain Shape Index (3) depth of the A horizon and (4) presence/absence of B horizon. The discriminant function had a classification success of 80 percent using resubstitution and 69 percent using cross-validation.

Axis Interpretation

The clusters found by DECORANA exhibited a moisture gradient across the landscape. The first axis in the ordination relates to a moisture gradient (figure 1). This can be seen in the vegetation but corresponding environmental and soil variables are difficult to interpret. Several studies have shown soil texture and depth to clay to be a surrogate for soil moisture (Marks and Harcombe 1981, Jones 1989) but no clear relationship can be seen here. There can be no doubt that the underlying factors affecting moisture on the sites are heavily correlated with soil texture and topography. However, the history of past land uses and disturbance in the study make it difficult to determine these relationships among the vegetation, soils, and landform.

Ecological Site Unit Descriptions

Each cluster defined by ordination/classification revealed a distinguishable group of vegetation and set of associated physical variables. This assemblage of species and physical variables forms the basis of the site units. Due to the wide range of sites sampled, the presence or lack of a B horizon was the most significant environmental variable discriminating among site units.

Hydric Site Unit

The hydric site unit is characterized by an overstory of swamp tupelo *(Nyssa biflora)* and pondcypress *(Taxodium* ascendens). Fetterbush (*Lyonia lucida*) and Virginia willow (*Itea virginica*) dominated the understory. There was no dominant herbaceous cover in the hydric site unit.

In the hydric site unit the B horizon thickness averaged 31.7 inches. The average A thickness was 14.9 inches. The average Landform Index (LI) was 0.14. The average TSI for the hydric plots was 0.01.

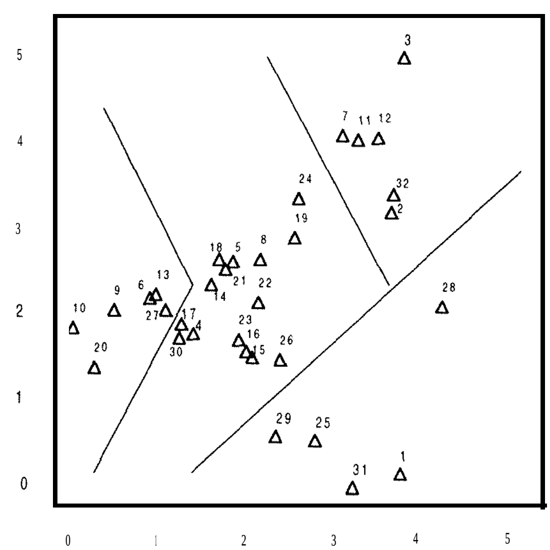

Figure i-Presence/Absence Ordination of 32 plots and 307 species.

Mesic Site Unit

There. was no overstory vegetation associated with the mesic site unit. The understory was dominated by the shrub American beauty-berry (*Callicarpa americana)* and flowering dogwood (*Cornus florida*) in the sapling stage. The herbaceous cover consisted of three vines: supplejack *(Berchemia scandens),* Virginia *creeper (Parthenocissus quinquefolia*) and variety of muscadine (*Vitis labrusca*).

Landform index had a mean of 0.22 in the mesic site unit. The average Terrain Shape Index (TSI) was 0.007. The average A horizon thickness for the mesic site unit was 2.7 inches. The average B horizon thickness was 43.2 inches. There was no C horizon within the upper 50 inches of the soils in this site unit.

Submesic Site Unit

Tupelo (*Nyssa sylvatica*) dominated the overstory of the submesic site unit and Water oak *(Quercus nigra)* saplings characterized the understory. The herbaceous covers were predominantly red chokeberry *(Aronia arbutifolia*), and netted chain fern *(Woodwardia areolata*).

The submesic site units had an average A horizon thickness of 9.0 inches and an average B horizon of 34.0 inches. The average Landform Index was 0.1 and the average Terrain Shape Index was 0.01.

intermediate Site Unit

The intermediate site unit had an overstory dominated by longleaf pine (*Pinus palustris)* and a shrub-like oak, running oak *(Quercus pumila*) characterized the understory. The herbaceous covers consisted of black-root *(Pterocaulon pycnostachyum)* and bracken fern *(Pteridium aquilinum).*

This site unit had an average C horizon thickness of 37.8 inches and 70.6 percent sand in the C horizon. The average A horizon thickness was 5.1 inches, there was no B horizon found in this site unit and Terrain Shape Index and Landform Index averaged 0.01 and 0.07, respectively.

Historic Witness Trees Associated with Field Plots

Ail historic witness trees located within 200 meters of the field plots were compared with the present day species occurring in the field plots. This portion of the analysis was accomplished using the GIS since none of the historic trees could be located on the ground.

Relative frequency of witness trees and present day trees was also examined. In the intermediate site unit, longleaf pine was represented in 100 percent of the plots by witness trees and present day trees. Tupelo (swamp or water tupelo) occurred in 25 percent of the intermediate site unit plots as a witness tree but did not occur in the present day field sampling.

In the sub-mesic site unit, Longleaf pine was represented on 87 percent of the plots by witness trees and 33 percent by present day trees. Pondcypress or baldcypress *(Taxodium distichum)* occurred 27 percent as a witness tree and 13 percent as a present day tree. Red maple (*Acer rubrum*) occurred only 6 percent as a witness tree but 60 percent as a present day tree. Blackgum was represented on 6 percent of the plots by witness trees and 47 percent of the plots by present day trees. As a witness tree, r. oak (red oak) occurred on 6 percent of the plots while oaks (in general) occurred on 100 percent of the plots as a present day tree. Bay (sweet bay *(Magnolia virginiana)and* beech (*Fagus grandifolia*)both had 6 percent occurrence as a witness tree in this site unit while they did not occur as a present day tree.

In the mesic site unit, longleaf pine as a witness tree occurred in every plot (100 percent) but did not occur as a present day tree. Water oak was represented by witness trees in 2.5 percent of the mesic site unit plots and 50 percent as a present day tree. Poplar (yellow-poplar *(Liriodendron tulipifera*)) occurred in 25 percent of the plots as a witness tree but did not occur as a present day tree.

In the hydric site unit, longleaf pine occurred 50 pecent as a witness tree and did not occur as a present day tree. Tupelo occurred 17 percent as a witness tree and 100 percent as a present day tree. P. oak (post oak *(Quercus stellata*)) and water oak *(Quercus nigra)* occurred 17 percent as witness trees but did not occur as present day trees in the hydric site unit.

DISCUSSION

Methodology used in plot location of this study differed from traditional LEC. To achieve accurate representation of the relationship between environmental variables and vegetation, LEC plots are located in areas with "steady-state" vegetation. Field plots in this study were positioned around the relative locations of known witness trees regardless of the state of the present day forest. For this reason, plots were distributed through a wide range of vegetation and sites that varied from dry, xeric uplands to standing water wetland areas. Since the determination of plots was based on the location of witness trees, some communities were excluded from the plots. For this reason, the classification may not necessarily represent a continuum in vegetative communities across all environmental gradients. It should be noted that none of the witness trees were located on the ground.

Four distinct vegetative communities were delineated occurring across a soil moisture gradient. These site units were found to reoccur on the landscape. Soil texture and terrain shape had significant influences on the moisture regimes across the landscape. Percent clay and depths to the clay were all discriminating variables in the site units delineated by discriminant analysis. This study demonstrated environmental variables that can be related to vegetation in areas of high disturbance such as the southeastern United States although they may not be the only factors at work shaping vegetation.

The incorporation of historical records into a GIS can greatly aid in spatially viewing past vegetation and land use. This was integral in mapping historic witness trees and the comparison of past and present day vegetation. The decrease in longleaf pine since the time of the historic records was the most apparent pattern.

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APPLICATION OF PIEDMONT LANDSCAPE ECOSYSTEM CLASSIFICATION AS A REFERENCE FOR A VEGETATION AND HERPETOFAUNAL SURVEY ON LAKE THURMOND, SC

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Abstract-Application of a Piedmont landscape ecosystem classification methodology was used as a basis for a survey of vegetation and herpetofaunal communities on a 343 hectare (846 acre) tract on Lake Thurmond near Plum Branch, SC. The site is located in the Carolina Slate Belt of the Midlands Plateau Region of the Piedmont province. A total of 160 plots were established and 30 were sampled intensively for vegetation. Herpetofaunal populations were sampled within 6 sites, representative of habitat types found throughout the site, using drift fences and pitfall traps.

Nearly 180 species of plants were documented and classification and ordination revealed the expected array of plant communities in an area that has not as yet achieved a steady state plant community. Landscape Ecosystem Classification revealed five site units in a repeating pattern across the site. Herpetofaunal communities were documented across the area by habitat type. Thirty species of herpetofauna were captured or otherwise recorded. This total included species from 2 classes (Amphibia, Reptilia), 4 orders (Caudata, Anura, Testudines, Squamata), and 2 suborders (Lacertilia, Serpentes). Species richness and abundance were greatest at depression wetlands (18), followed by riparian zones (16) and uplands (11). Depression wetlands and riparian zones should be given the highest priority in conserving critical habitats for herpetofauna on the training site.

Through the use of geographic information systems (GIS), a map showing the location of the various site types in relation to the vegetation and herpetofaunal communities was produced. These data may provide valuable reference information for the landowner.

INTRODUCTION

The South Carolina Army National Guard (SCARNG) and the Department of Forest Resources at Clemson University developed a cooperative research project to survey the vegetation and herpetofaunal resources at the SCARNG's Clarks Hill Training Site. The project included four phases or components: 1.) a vegetative communities survey, 2.) a flora survey, 3.)a herpetofaunal survey, and 4. the development of a geographical information system (GIS) for storing and displaying data associated with the three surveys.

The application of a Piedmont Landscape Ecosystem Classification methodology was used as a basis for determining forest communities and as a framework to survey the area's flora (Jones 1991). The methodology uses percent clay in the B horizon, depth to maximum clay, landform index, terrain shape index, and aspect as discriminators in classifying sites along a continuum from xeric to mesic.

The Piedmont is one of the most anthropogenically disturbed physiographic regions in the southeastern United States. According to Godfrey (1997), forests regenerating on abandoned agricultural lands dominate the central Piedmont. As such, the area "...offers splendid laboratories in which to watch the advance of plant succession." (Godfrey 1997). Over 130 species of reptiles and amphibians have been recorded in South Carolina (Martof and other 1980, Zingmark 1978). Standardized methods were used to survey reptiles and amphibians inhabiting the training site and to assess the herpetofauna community composition and distribution in representative habitats across the site (Heyer and others 1994). For species of particular interest (high abundance, conservation concern, extralimital occurrence) notes on natural history and management implications are also included.

The results of the vegetative communities survey, flora survey, and herpetofaunal survey were incorporated into a GIS for data storage and display. These results were compiled into a series of themes or layers suitable for use by by ArcView® and/or ArcInfo®.

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OBJECTIVES

1. Describe the distribution and extent of plant alliances on the Clarks Hill Training Site.
2. Map the areal extent of ecological landtype phases using the Piedmont Landscape Ecosystem Classification (LEC) model.
3. Survey the site for vascular plants using verified nomenclature, classification and annotation.
4. Denote plots and flora listing with an associated map showing plot locations as determined by GPS.
5. Record species of reptiles and amphibians in representative habitats.
6. Render management recommendations regarding the conservation of herpetofauna communities.

METHODS

Study Site

The 343 hectare (846 acre) Clarks Hill Training Site tract is a peninsular landform bounded by Lake Thurmond (Clarks Hill Lake). The training site is located within the Carolina Slate Belt in the South Carolina Piedmont physiographic province (Myers and others 1986). Terrain in this region is typified by narrow floodplain bottomlands, streams and gently rolling uplands. Elevation ranges from 37 m to 214 m above mean sea level.

Most of the soils are Typic Hapludults with occasional Aquic Hapludults and Typic Dystrochrepts (Gay 1992, Smith and Haybeck 1979). Surface horizons are usually brown and loamy with an underlying argillic clay horizon. The growing season is approximately 215 days from late March to early November and the average rainfall of 120 cm is evenly distributed throughout the year (Gay 1992). The dominant forest cover type is a relatively homogeneous natural stand of 50-60 year old loblolly pine (*Pinus taeda*). Visual inspection of the site indicated historical disturbances (probably agricultural). Lotic water features within the training site include several "dry" branches (intermittent creeks) that flow into some of the lake's many coves. The only known lentic features within the site were 4 depression wetlands. These wetlands had a higher proportion of hardwood species than surrounding upland sites.

Methodology and Data Analyses: Ecosystem Classification
A 20m x 20m plot was established in the fall of 1999 at each point using the methodology as described in the North Carolina Vegetation Survey (NCVS) (Peet and others 1998). Plots were usually located in the geometric center of the stand but were occasionally adjusted to insure homogeneous species composition and uniform stand structure within the plot. The tree stratum (dbh > 11.4 cm) was sampled by species and diameter within the 0.10 ha plot, and the sapling and shrub stratum (>1.4 m tall, less than 11.4 cm dbh) was sampled by species and diameter class as indicated by the survey methodology. Tree seedlings, low shrubs, herbaceous species, and rhizomatous shrubs were tallied by species and in frequency classes in the whole plot.

Landform and soil variables were also examined at each plot. Landform index was derived from the mean of eight measurements in percent scale taken with a clinometer at forty-five degree spacings from plot center to the surrounding horizons. Terrain shape index (TSI) was determined at each plot to determine microsite convexity or concavity. Soil samples were systematically collected from three locations within the plot using an auger. Using averages from the three collection sites, depth of A and E horizons, epipedon thickness, and soil solum depth were determined. Vegetation data are summarized by species for each intensive plot. Cover classes for all species (trees, shrubs, herbs, vines, and seedlings) are noted for each plot. Plots are then referenced on maps within a GIS (phase 4 of this project).

Presence is defined as the occurrence of a species (based on emergence of a stem or stems) within an area of a given size and location. Presence is a vegetation parameter compatible across all plant growth forms that can be used for many analytical procedures (ordination and classification). Presence/absence data taken from the nested plots in the NCVS provide fundamental data for characterization of community composition and structure (Peet and others 1998).

Cover is defined as the percentage of ground surface obscured by the vertical projection of all aboveground parts of a given species onto that surface. Percentage cover provides an index of a species' potential contribution to community production. In the NCVS protocol, cover is the only quantitative vegetative parameter compatible across all plant growth forms. Percent cover was estimated visually by the researcher during this study. The cover classes and percentage cover ranges that used in this study were: 1 = trace, 2 = O-l percent, 3 = l-2 percent, 4 = 2-5 percent, 5 = 5-1 0 percent, 6 = 1 O-25 percent, 7 = 25-50 percent, 8 = 50-75 percent, 9 = 75-95 percent, 10 > 95 percent (Peet and others 1998).

A series of multivariate techniques was used for analysis of data. Detrended Correspondence Analysis (DCA) (DECORANA, Hill 1979a), which ordinates species and samples simultaneously, was the method of ordination used to analyze vegetation data (McCune and Mefford 1999). DCA or DECORANA" was used to analyze species abundance by organizing and displaying data in multidimensional space (Hill 1979a).

Cluster analysis of vegetation was performed by Two Way Indicator Species Analysis (TWINSPAN, Hill 1979b). TWINSPAN" is a polythetic diverse classification that simultaneously classifies both species and plots using the main matrix for vegetation data (McCune and Mefford 1999). This is a subjective classification, and allows the investigator to draw a separation between the groups in the initial ordination of plots (Hutto and others 1999). TWINSPAN was used in conjunction with DCA to reduce this subjectivity while delineating groups of similar plots. TWINSPAN was also used to identify indicator or diagnostic species that were strongly correlated to a certain community association.

A landscape ecological classification model developed by Jones (1988, 1991) was employed. This model uses depth

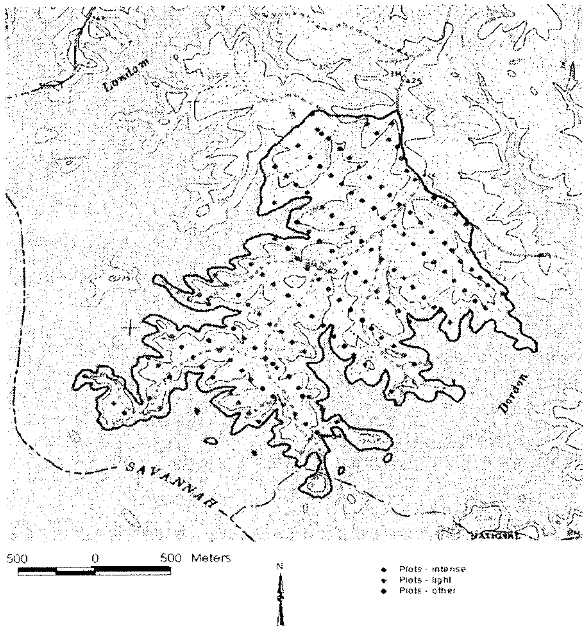

Figure l--Location of 160 plots on the South Carolina Army National Guard training site on Lake Thurmond in South Carolina.

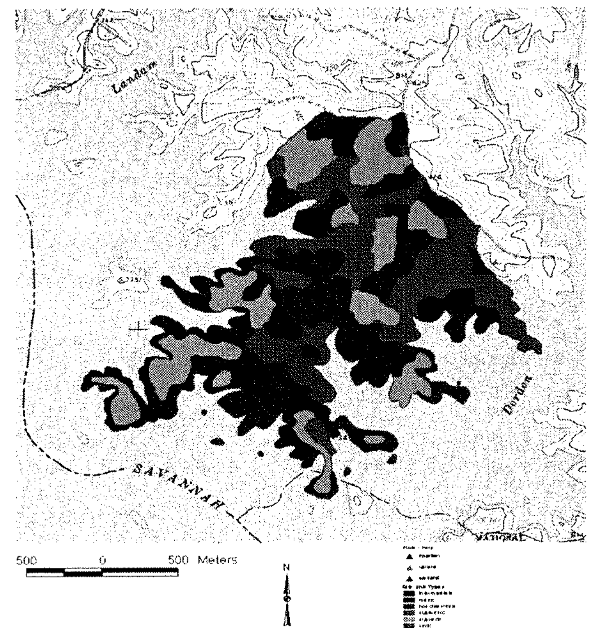

Figure 2-Five site units, determined by Landscape Ecosystem Classification, South Carolina Army National Guard training site on Lake Thurmond in South Carolina.

to maximum clay, percent clay, aspect, landform index and terrain shape index. The actual basis for using this model is based on the conclusion by Gay (1992) that the Jones model for the Interior Uplands Plateau in the Piedmont was compatible with the Slate Belt Subregion in the Piedmont. Transects were established throughout the site at an approximate sampling ratio of one survey plot for every five acres. Transect lines were spaced 201.2 meters (10 chains) apart and plot centers were located at intervals of 100.6 meters (5 chains) along the transect lines. Global positioning system (GPS) technology was used to record the location of the plot centers. On each of the 160 plots, data on Landform Index, aspect, soils and presence/ frequency of overstory species were collected. Every fifth plot of this systematic sample was designed to be an "intensive plot" where additional data on the understory flora were collected. This process resulted in 30 intensively surveyed plots and 130 lightly surveyed plots (figure 1). Al! data were compiled by cover type and landtype phase (mesic, sub-mesic, intermediate, sub-xeric and xeric) by plot in both tabular and map formats.

Herpetofaunal Sampling

Six study sites, representative of the habitat types of the surrounding landscape, were established for herpetofaunal sampling. These sites included 2 depression wetland sites, 2 riparian sites along creeks, and 2 upland sites. Trapping methods included drift fences with pitfalls and cover-boards. Drift fences were 10m long x 0.6m high silt cloth with 2 pitfall traps (each a 5 gallon bucket, buried flush with the soil surface) at each end of the fence for a total of 4 pitfalls/fence. A total of 24 fences (4/ site) and 96 pitfalls (1 G/site) were installed among depression wetland, riparian, and upland sites. A total of 24 coverboards (0.6m x 1.2m, plywood and tin) were installed within two of the study sites (12 within a riparian site and 12 within a depression wetland site). During monitoring sessions, aural surveys were conducted to record the presence of frog (Anuran) species. Area/time constrained searches to record species or individuals that may not have been captured in traps, were also conducted. Individuals that were captured were identified to species and sex (when possible), and released on the opposite side of the drift fence from which they were captured.

RESULTS AND DISCUSSION

Ordination and Cluster Analysis

Ordination arranged the intensive plots along two axes that together represented a possible soil moisture gradient. Based on ordination and cluster analysis (classification), the plots were separated into three groups. An evaluation of the classification analysis for all plots indicated that there were many plant species which were not preferential; in other words, many species were not found in greater abundance in one group over another. This pattern fits the expectation for the earlier stages of succession which these plots mostly represent.

Community and Floral Survey

Most of the tract is dominated by 50 • 60 year old loblolly and shortleaf pine. Five site units were mapped on the site (figure 2): Xeric (3.6 hectares: 1 percent of the area): Sub-xeric (77 hectares: 23 percent); Intermediate (156 hectares; 46 percent); Sub-mesic (89 hectares; 26 percent); Mesic (15 hectares; 4.5 percent); 180 plant species were described on the 30 intensive plots.

A description of these site units is as follows. 1.) Xeric sites are the driest, most exposed sites. They are the most unproductive sites since either a combination of high clay content close to the soil surface or the location of the site (i.e., exposed ridges which do not retain moisture) makes for poor growing conditions for most species. Loblolly pine site index (index age 50) is generally 60 feet on these xeric sites. 2.) Sub-xeric sites exhibit slightly higher productivity either through a combination of lower clay content, greater depth to maximum clay or less exposure. This is a fairly common site type throughout the South Carolina Piedmont. Site index for loblolly pine in these sub-xeric sites is approximately 70 feet. 3.) The intermediate site unit is also fairly common and makes up the plurality of sites on this tract. Clay is usually not as close to the soil surface or there is some combination of aspect and exposure which provides a greater degree of site protection creating higher moisture retention in the soil. Site index for loblolly pine in these intermediate sites is approximately 80 feet. 4.) Sub-mesic site units usually exhibit a much reduced clay content that is at least 12 inches or more from the soil surface. Likewise, landform indices are generally high, reducing exposure to the drying effects of the sun. These sites generally occur on lower and north facing slopes where there is greater moisture retention due to runoff from upper slopes and more protection. Site index for loblolly pine in these sub-mesic sites is approximately 90 feet. 5.) Finally, mesic sites exhibit a combination of low clay content, high landform indices and north facing slopes. However, not all three factors must be present for a mesic site to occur. These sites also occur along stream bottoms and cove sites. They exhibit the greatest degree of moisture retention because of their place on the landscape. Site index for loblolly pine in these mesic sites can exceed 100 feet.

The determination of site unit scores and the actual location of site units is subject to some error. At best, there is a 20 percent chance that any particular point will be either a site unit higher or lower than is actually determined. This is due to microsite variations not picked up in the sampling scheme. Also, there is some inherent error in the model itself. Therefore, these data and mapping units are most suitable for planning purposes in terms of overall site productivity of an area.

Herpetofaunal Survey

Thirty species of herpetofauna were captured or otherwise recorded as occurring on the training site from May 12, 2000 through January 27, 2001. This total included species from 2 classes (Amphibia, Reptilia), 4 orders (Caudata, Anura, Testudines, Squamata) and 2 suborders (Lacertilia, Serpentes). Species richness and abundance were greatest at depression wetlands (18), followed by riparian zones (16) and uplands (11). Ambystomatide salamanders (mole salamanders) were the most frequently captured taxa among all sites with most captures occurring in depression wetlands.

The overall herpetofauna richness (represented as the number of species), showed a relatively uniform distribution by taxa. The taxon with the fewest species was Testudines (four turtle species), and the taxon with the greatest number of species was Serpentes (nine snake species). The overall herpetofauna abundance (represented by the number of individuals captured or observed) shows an unequal distribution by taxa. There were relatively few individuals in the order Testudines and suborder Serpentes and a moderate number in the order Anura (frogs) and suborder Lacertilia (lizards). The order Caudata had the greatest number (476) of individuals captured or observed.

The depression wetlands habitat type had the greatest number of individual amphibian captures (542) while the riparian and uplands habitat types had fewer individual amphibian captures (33 and 16, respectively). However, the number of individual reptiles was fairly uniform across all three habitat types. Separating the two classes into orders and suborders shows that the greatest number of individuals captured was salamanders in wetland depression sites (456 individual captures). Though of lesser numbers, the dominant taxa in the riparian habitats were salamanders and frogs. Lizards were the dominant taxa in the upland habitat (22 individual captures).

CONCLUSIONS AND RECOMMENDATIONS

The Piedmont Landscape Ecosystem Classification methodology provided a working framework for classifying sites on the tract. Although classification of the sites provided a framework for a floral survey, ordination and classification of the vegetation did not distinguish between the five site units due to the mid-successional status of the landscape. Depression wetlands and riparian zones should be given the highest priority in conserving critical habitats for herpetofauna. This should include reserving appropriate buffers around depressions and along streams.

Species most sensitive to disturbance are likely to be Ambystomatid salamanders (mole salamanders). These species rely on ephemeral wetlands for breeding habitats. The occurrence of *Ambystoma talpoideum* (mole salamander) at the training site is noteworthy since it is believed to occur mostly as a Coastal Plain species in South Carolina. Surrounding uplands are important as buffers but also as non-breeding habitats for many species. The four-toed salamander (*Hemidactylium scutatum*), a disjunctly distributed species, occurs on the training site in riparian areas and areas adjacent to wetland depressions. By nature of its limited distribution in South Carolina, its status and conservation should also be a priority.

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COARSE WOODY DEBRIS OF A PRERESTORATION SHORTLEAF PINE-BLUESTEM FOREST

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Abstract-The shortleaf pine-bluestem ecosystem was once a significant component of the Ouachita Mountains. However, fire suppression over the past century has reduced this complex. To address this loss, the Ouachita National Forest plans to restore approximately 155,000 acres of shortleaf pine-bluestem through understory, overstory, and fire treatments. We do not fully understand effects of these treatments on biotic and abiotic components of the forest. Our study of one component, coarse woody debris, is a portion of a larger study to examine ecosystem changes. Our treatments will include overstory thinning to 65 feet* per acre (approximately half that of the control), removed of the midstory and understory, and moderate intensity fires at 2- to 5-year intervals. Pretreatment values indicate total coarse woody debris volume (standing + down) did not differ between control and treatment (treatment area = 94 $feet^3$ per acre (SE $\pm$ 10.3); control = 110 $feet^3$ per acre (SE $\pm$ 46.9)), (p-value = 0.62, a = 0.05). However, due to initial differences in the woody debris components (e.g., species and decomposition class) between the pre-treatment area and control area, percent change within the pre-treatment area will be a better measure of change over time.

INTRODUCTION

Coarse Woody Debris

Coarse woody debris is important as habitat for forest organisms (Larson 1992, Maser and others 1979, Maser and others 1988, Maser and Trappe 1983, Meyer 1986, Muller and Yan Liu 1991, Thomas and others 1979, Van Lear 1993) and acts as reservoir for nutrients and carbon (Bray and Gorham 1964, Edmonds 1987, Harmon and others 1986, Lang and Forman 1978, Maser and others 1988).

Many organisms are associated with standing and down wood. Forty-five bird species use standing dead trees and 20 species use down woody debris in southern US forests (Lanham and Guynn 1996). In the southeastern US, at least 23 mammal species use standing dead trees and at least 55 mammal species use down wood (Loeb 1996). Ausmus (1977) found greater organic matter, nematode density, and root biomass in soil beneath log litter than under leaf litter. Reptiles and amphibians have been associated with coarse woody debris and their diversity may be linked with the quality and amount of coarse woody debris (Whiles and Grubaugh 1996). Earthworms may use deadwood for cover and microbial biomass as food (Hendrix 1996). Finally, Barnum and others (1992) found that mice select down logs as the most widely used substrate for travel in Minnesota and Maryland.

Ecosystem Management Research Project

The Ouachita Mountains Ecosystem Management Research Project (OEMP) is a large-scale interdisciplinary effort designed to provide the scientific foundations for watershed scale landscape management. The OEMP has progressed through three phases: developing natural regeneration alternatives to clearcutting and planting, testing these alternatives at the stand scale, and measuring cumulative impacts of landscape scale ecosystem management in the Upper Lake Winona Watershed. We divided this 16,274-acre watershed into six sub-watersheds, each with different management objectives and treatments. One of these, and the focus of this paper, is the 3,370-acre North Alum Creek sub-watershed, which is being managed to recreate a shortleaf pine-bluestem ecosystem.

The management goal is to restore a vegetation complex that existed prior to European settlement of the region. This vegetation complex was dominated by pines, primarily shortleaf (*Pinus echinata Mill*), with a minor hardwood component (mostly *Quercus* spp.) in the overstory. Frequent fires maintained a herbaceous understory dominated by bluestem grasses *(Andropogon gerardii Viaman* and *Schizachyrium scoparium* (Mich.) Nash), and restoration is designed to mimic these conditions. Treatments applied to the North Alum Creek sub-watershed will include overstory commercial thinning, midstory and understory removal, and cyclic burning.

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Over time, an area-based approach using even-aged reproduction methods, primarily two-aged shelterwoods, will achieve sustainability. Approximately 155,000 acres of shortleaf pine-bluestem ecosystems are planned to be restored on the Ouachita National Forest in Arkansas and Oklahoma.

In this study, we examine coarse woody debris (CWD) of the control area versus the proposed treatment area (defined as the pre-treatment area). Our long-term objective is to determine differences in volume and structure between the control and the restored site. The immediate objective of this study, summarized in this paper, is to compare baseline woody debris between an unharvested, unmanaged control area to the pre-treatment area.

METHODS

Future Treatment

Total basal area of the restoration treatment (65 feet^2 per acre) will be approximately half that of the control (118 feet^2 per acre). Hand lobor using chainsaws or handtools will remove the predominantly hardwood midstory and understory. We will conduct burning at 2- to 5-year intervals for 10 years, during the dormant or growing season, with moderate intensity fires. The resulting stands will be open and park-like.

Plot Layout and Measurements

We established 77 one-fifth-acre circular plots with a 52.7 ft radius, 65 plots located in the pre-treatment area and 12 in the control area. In each plot we measured both standing dead trees (snags) and down deadwood.

We measured all snags at least 4 inches d.b.h. on the fifth-acre circular plot. For each tree we recorded species, d.b.h., and height. We recorded five decay classes for hardwood trees and six classes for pines (table 1). These classes are:

(1) recently dead with tight bark, twigs and small branches present;

(2) dead, small branches broken, bark - loose and/or partly absent;

(3) dead, mostly large branches present, bark - trace to absent;

(4) dead with bark absent: broken top; heavily decayed; soft, blocky structure (a 6-inch knife blade can be easily inserted 3 inches or more into the wood);

(5) soft and powdery or down (for snags this is a post-treatment measurement only);

(6) (Pine only): all but heartwood has decayed and fallen away.

For down wood ≥4 inches in diameter, in fifth-acre plots we measured length and midpoint diameter (figure 1). We recorded branches larger that 4 inches in diameter as separate pieces indicated by numbered segments (figure 1).

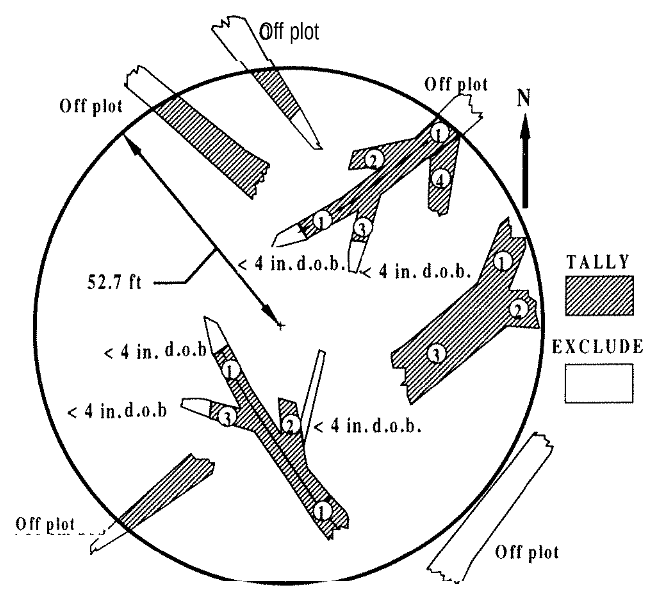

Figure 1-A typical fifth-acre circular plot. We measured all down deadwood ≥ 4 inches in diameter on the plot. Numbered segments were measured separately. Additionally, all standing dead trees (snags) ≥ 4 inches d.b.h. were measured on the plot (snags not pictured).

We calculated snag volume as:

$V = 1/3 \times H \times [B + B' + \mathrm{sqrt}(B \times B')]$

Where: V = volume in ft^3

H = height of tree main stem (ft)

B = cross sectional area of tree at dbh (ft^2)

B' = cross sectional area at the top of the stem (ft^2)

We calculated down deadwood volumes (feet^3) as length of segment multiplied by the midpoint cross sectional area. We compared mean volume of course woody debris between plots in the pre-restoration and control area plots using a one way ANOVA, alpha 0.05.

RESULTS

Total coarse woody debris volume (standing snag + down wood) was similar, with 110 feet^3 per acre in the control and 94 feet^3 per acre in the pre-treatment area. These values did not differ statistically (p-value = 0.62, a = 0.05) (figure 2). However, pine snag volume in the control plots was nearly double that of pre-treatment plots (figure 3). For down deadwood of pine, just the opposite was true, with a mean of 2.4 feet^3 per acre in the control plots versus 13.7 feet^3 per acre in pre-treatment plots.

Decomposition class 3 of the pine snag component in the control area had greater mean volume than any other class (figure 4). Class 4 dominated the pine down deadwood component in both the control and pre-treatment area (figure 5).

DISCUSSION AND CONCLUSIONS

Surprisingly decomposition class 5 was rarely recorded on our plots, although nearly all previous studies have shown this as a major component. However, class 5, often hidden

Table l-Breakdown of decomposition classes for snags and down wood. Decomposition class 1 represents the least decomposed woody material and class 5 is the most decomposed woody material. Adapted from Cline and others (1980) and Maser and others (1979)

		Decomposition class				
Dead-wood type	Characteristic	1	2	3	4	5
Snags	Branches and Crown	recently dead, twigs and small branches present	large branches present, mostly broken	large branch stubs present	absent	NA
	Bark	tight	loose and/or partly absent	trace to absent	absent	NA
	Bole	recently dead	standing, firm	standing, decayed	broken top, heavily decayed, soft, blocky structure	NA
Down wood	Bark	intact	intact	trace to absent	absent	absent
	Twigs > 1.2 in.	present	absent	absent	absent	absent
	Texture	intact	intact, sapwood partly soft	hard, solid interior, possible evidence of exterior decay	soft, blocky pieces	soft and powdery
	Shape	round	round	round	round to oval	oval
	Color of wood	original color	original color	original color to faded	original color to faded	heavily faded
	Portion of log on ground	log elevated on support points	log elevated on support points	log near or on ground	all of log on ground	all of log on ground

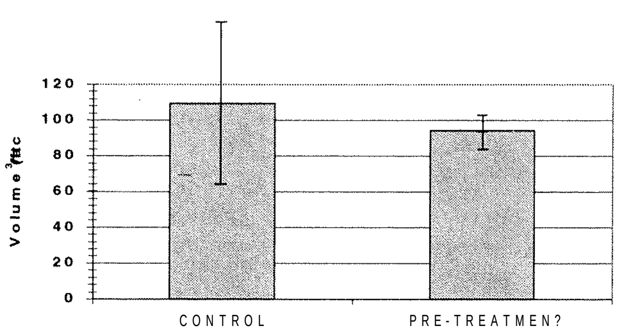

Figure 2-Total mean volume of standing plus down deadwood. Error bars represent standard error.

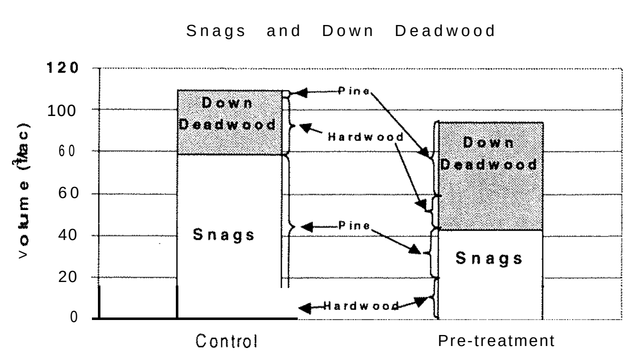

Figure 3-Snags and down deadwood volume (feet^3 per acre) by pine or hardwood in control and future treatment area.

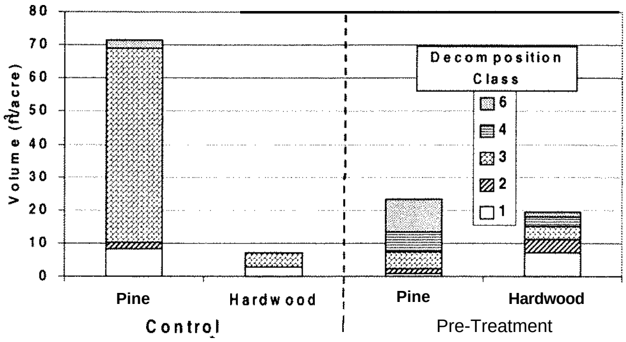

Figure 4-Mean volume of snags by species and decomposition class in control versus future treatment area. We used decomposition class 5 only for down deadwood.

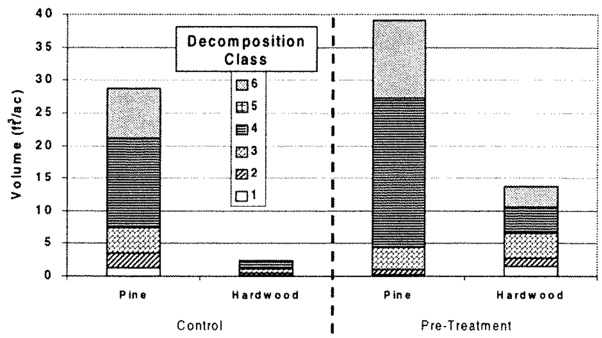

Figure 5-Mean volume of down deadwood by species and decomposition class in control versus future treatment area. Note that class 5, found only for pine on the pre-treatment area, was 0.1 feet^3 per acre.

under leaves, is the most difficult to detect. We plan to re-sample some plots to examine the possibility of undersampling. If not a sampling error, then this result would require closer examination of the dynamics and interacting organisms in the class 4 stage and beyond.

Other studies have found intermediate decay classes, such as our class 3, tending to be dominant (Harmon and others 1986, Shifley and others 1997, Spetich and others 1999, Spies and Cline 1988). However, only the pine snag component in the control area showed this relationship. Decomposition class 4 currently represents the largest volume when compared to the other decomposition classes.

For decomposition class 6 resin-impregnated pine is highly flammable, and the fire treatment will likely reduce its volume.

Post-treatment comparisons of deadwood volume in this study will require testing total deadwood volume changes between the control and treatment areas. Due to initial differences or high variability in the components (e.g. hardwood versus pine and decomposition class) between the treatment and control areas, percent and rate of change will be a better measure of comparison over time.

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